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ADVANCED DEVELOPMENT OF INSENSITIVE PBX'S FOR LESS VULNERABLE MUNITIONS

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ABSTRACT

Three approaches that can be taken to formulate safer explosives are:

(1) Use of low energy explosives;

(2) Use of fuel/oxidizer mixtures,

And (3) Use of soft, rubbery explosives.

Munition vulnerability is strongly affected by the explosive's properties, but is also very dependent on the warhead physical characteristics. Other things that affect vulnerability include the quality of the explosive charge, ambient conditions, the presence of other ordnance items, and the way external energy is deposited into the explosive.

An insensitive explosive must not react easily to external stimuli, or must react mildly under a variety of conditions. The difference in sensitivity must be large enough in practical situations to be worthwhile. Test results will be discussed that show that certain new, high-performance explosives also have exceptionally good vulnerability behavior.

INTRODUCTION

For over twenty years, the Navy has been developing two new types of explosives that have demonstrated exceptionally good vulnerability behavior compared to conventional TNT-based melt-cast explosives and standard pressed explosives. Previously, applications requiring good vulnerability have resorted to using low-energy explosives, such as Explosive D, DATB and picric acid. The poor performance characteristics of such explosives restricted their use to situations where there was no alternative. Aircraft carrier fires, train fires, and other accidents that have produced violent explosive reactions have pointed out the need for less vulnerable munitions. It has also been shown that the vulnerability of complex, high-value

launch platforms, such as tanks and ships, is very dependent on the vulnerability of on-board munitions. Above-the-waterline storage of ordnance on ships has caused concern about the impact of this on ship survivability.

This paper describes fairly recent developments by the Navy of two types of high-performance, insensitive plastic bonded explosives (PBX's). The insensitive PBX's are soft, rubbery explosives that have energetic, powdered solids incorporated into polymeric binders. While these explosives have been under development for quite a few years, there is still some concern about their use in munitions because they have unusual properties. They appear to be sensitive when tested in some standard tests, such as the small-scale drop-weight impact tester. Furthermore, the new PBX's are similar to composite propellants, have more complicated compositions, cannot normally be processed in standard explosives production facilities, and are expected to cost more than TNT explosives.

The Navy has taken several actions to emphasize the need for less vulnerable explosives and to facilitate their introduction into service use. One action was to issue an Operational Requirement (OR) document defining the need for insensitive and high performance explosives. The second was to establish an Explosives Advanced Development (EAD) Program to address the producibility of and to more fully characterize promising new explosives, including conducting large-scale tests in actual or simulated warheads to demonstrate their behavior. The purposes of these EAD Program efforts are to reduce the cost of weapons using new explosives and to minimize engineering development program risks when they are selected for weapon applications.

INSENSITIVE PBX'S

The first family of PBX's that were found to have good vulnerability behavior compared to molecular explosives, such as TNT, RDX, and mixtures of these, were explosives containing fuel and oxidizer rich ingredients formulated for use as underwater explosives. Development of these explosives started in the late 1950's. They are castable materials that cure to rubbery solids. The compositions of two of these explosives are shown on Table 1. The separate fuel and oxygen rich ingredients react during the detonation process to achieve the desired output. Some of the properties of these underwater explosives are shown on Table 2. They appear sensitive based on the small-scale, drop-weight impact test (easy to ignite), but are insensitive based on the large-scale gap test (LSGT) and have large critical diameters.

Development of a second family of PBX's, with good munition vulnerability properties and good performance in fragmentation warheads, started in the mid-1960's. An example of this kind of PBX is shown on Table 3. These PBX's are high-solids content, castable explosives that also cure to rubbery solids. They generally contain the nitramines, RDX or HMX, and sometimes aluminum (AL) powder. The PBX example shown contains a moderately energetic plasticizer. Other PBX's in this family have been formulated with all "inert" binders using commercially available elastomeric polymers, including polyurethanes and polyesters. Properties for the PBX shown on Table 3 are given in Table 4. These PBX's generally have mid-range drop-weight impact test heights (moderately easy to ignite), have moderate LSGT sensitivities, and critical diameters similar to standard explosives with comparable chemical energy.

One way the behavior of the insensitive PBX's deviates from past explosives is that the drop-weight impact test results do not correlate with field handling hazards. This was also found to be the situation for composite propellants containing ammonium perchlorate (AP). Such propellants could not be detonated even as large diameter charges, in spite of the fact that they had drop-weight impact sensitivities comparable to booster explosives. The good vulnerability behavior of the insensitive PBX's is apparently due to their soft, rubbery properties, to the fact that their cured density is close to the theoretical maximum density (TMD), to the way they fracture when loaded above their mechanical limits, and to their burning characteristics.

Explosive reaction to external shocks and mechanical energy sources is generally considered to be caused by hot-spots which grow, producing gas pressure that can cause structural failure of the case and explosive charge. Explosive breakup and other phenomena can lead to more violent reactions that can result in deflagration to detonation transition (DDT). It is believed that the rubbery PBX's distribute external energy sources throughout a greater volume of the explosive charge to reduce localized heating. If ignition should occur, the PBX burning characteristics and fracture mechanics apparently help to minimize reaction violence.

The composite underwater explosives complicate the ignition and growth process because of the use of relatively insensitive ingredients that produce a lot of energy by a diffusion, mass-transport burning process and because of their large critical diameters. The mixture of fuel and oxidizer chemicals increases the potential for explosive reaction (compared to the individual chemicals); however, the relatively long time that is needed to allow for gas phase mixing and the large critical diameter favor the continuation of burning reactions instead of DDT. This burning can be vigorous if confined and will produce pressure rupture explosions, but it is relatively slow, is much less likely to lead to detonation/mass detonation, and is possible to control by sprinkler systems or other damage control techniques.

EXPLOSIVES ADVANCED DEVELOPMENT

The assessment of new explosives, such as the PBX's described above, is difficult when they deviate from "normal" behavior. Weapon developers are reluctant to use new technology when it is not a simple extension of existing technology. The absence of historical data and lack of experience increases their reluctance. Under these circumstances, it is important to conduct large-scale tests to provide proof of explosive behavior and to demonstrate the ability to make correct predictions. Many tests are sometimes required to obtain reasonable estimates of mean values and their statistical variability, especially if there is a low probability that the event will occur.

The U.S. Navy has established an Explosives Advanced Dvelopment (EAD) Program to help move promising new explosive technology from the laboratory to use in weapons. The EAD Program supports the work efforts shown on Table 5. The purposes of these efforts are to reduce manufacturing costs and to reduce the risks associated with putting new explosives into munitions. Explosives are put through a five-phase test and evaluation process, shown on Table 6, that takes about five years to complete.

A compilation of test procedures is being assembled by the EAD Program to describe the testing that is done. The test procedures will include a description of generic test hardware and predictive techniques. The purposes for selecting special generic hardware are to use low-cost test units, to have consistency from test to test, and to obtain credible data on explosives behavior under realistic conditions for weapon applications. The generic test units are either simple, readily available items such as 76-mm and 127-mm gun projectiles, or specially designed items as shown on Figures 1 and 2.

Several similar explosives are often put through advanced development at the same time to compare them and select the best one. Methods have been prepared to rate explosives at different points during the five-phase development process. This is done using "ranking schemes" and is being done during development on explosives that are very similar, to reduce the number of explosives in advanced development and the cost of testing. The ranking schemes are used at the end of certain development test phases.

These ranking schemes are a collection of explosives properties (attributes) that are given point values based on how important the property is felt to be. The explosive being evaluated is given a rating for each property. Final scores are sums of the individual property ratings times the point value for that property. A ranking scheme used to evaluate

hazards and vulnerability is shown on Table 7. The PBX that receives the highest score is considered to be the safest or least vulnerable. The ratings determined for explosives evaluated using the safety ranking scheme are determined either on the basis of the violence of test results (no reaction up to a detonation), or on the basis of relative performance compared to some standard (for example, LSGT sensitivity compared to Comp B). The ranking schemes are intended to be fairly general, but are somewhat configured for classes of explosives, for example castable main-charge PBX's.

EXPLOSIVES VULNERABILITY TESTING

Some of the energy sources that can affect explosive hazards and vulnerability behavior of munitions are shown on Figure 3. Predicting hazards and vulnerability behavior is difficult. There are many conditions that can start a low level reaction, or ignition in an explosive; however, in many situations it is not possible to predict at what level this will occur. Once a substantial ignition of the explosive does occur, the problem of predicting the behavior of the munition is complicated by uncertainties concerning the growth process and violence of the final event. The two important questions are:

- What is the probability that an external stimulus will cause a persistent explosive reaction?

- What are the statistics of the response, that is, the level of the reaction and its variability?

An analysis of transportation accidents in the U.S. concluded that fire was the cause of explosive reaction in most, if not all, cases. Mechanical and hydrodynamic shocks also can be the cause of unintentional explosive reaction, in the handling of munitions, during combat, or as a result of violent explosive reaction of other munitions (sympathetic reaction).

The uncertainties associated with prediction of both munition performance and vulnerability behavior has placed emphasis on large-scale testing for assessing these kinds of behavior. Even for situations where adequate predictions can be made, large-scale testing is often done to confirm the predictions and to demonstrate explosive behavior. "Safety" tests, hazards tests, and vulnerability tests are included in most weapon development programs. Four tests that are required for many U.S. Navy weapons are the 12-meter (40-foot) drop, a fuel fire fast cook-off, a slow cook-off (3.3°C per hour to reaction), and a 20-mm bullet impact. Special tests

also are conducted on weapons, depending on the weapon's characteristics and the environments (including extreme environments) that the ordnance package is expected to see between the time it is loaded and the time it is used.

Typical results of the reaction of warheads to the Navy's WR-50 tests are shown on Table 8. The "pre-1970" results are representative of the behavior of conventional TNT-based and pressed explosives. Slow cook-off (heating at 3.3°C/hr until explosive reaction) produces the most violent reaction. Very seldom does the 12-meter (40-foot) drop produce any reaction, and if it does the warhead is redesigned to eliminate the cause. A compilation of WR-50 test results for PBXN-103 loaded into a number of different hardware test items containing from 45 to 550 Kg of explosive is shown on Table 9. Even though PBXN-103 is a very energetic explosive, it has good vulnerability characteristics.

A comparison of vulnerability tests conducted on a non-aluminized PBX (Table 3) loaded into generic 76-mm and 127-mm projectile test units with a standard projectile explosive, Composition A-3, is shown on Table 10. The PBX explosive produces less violent reactions in most of the tests, although the explosive will start to react at similar input levels. The time to ignition in the fast cook-off test is about the same for the PBX and Composition A-3, but the PBX only burns leaving the projectile intact. The Composition A-3 produces a partial detonation with air blast overpressures equivalent to a detonation of about one-half the explosive.

A sympathetic detonation test set-up is shown on Figure 4. The center, or donor projectile, is detonated. The distance between the two projectiles on either side, the acceptor projectiles, and the donor are varied to find the 50-percent probability standoff distance for sympathetic detonation. The PBX did not sympathetically detonate in either the 76-mm or the 127-mm configurations even when the acceptor projectiles were placed in contact with the donor. Figure 5 shows the acceptor projectile fragments for a 127-mm sympathetic detonation test at zero standoff. The 50-percent standoff distance for Composition A-3 was 18 to 25 cm.

The setback shock test is a drop test that subjects the explosive to a pressure pulse similar to the set-back pulse seen during gun firing. The setback shock test can be conducted at different pressure levels, up to six to eight times the pressure experienced during gun launch. The PBX and Composition A-3 start to react at similar pressure levels; however, the PBX produces very mild reactions while Composition A-3 produces violent explosions.

The safety and vulnerability attributes listed on Table 7 have been determined for new, insensitive, aluminized PBX's. Results of vulnerability tests for one are shown on Table 11. The fast ccok-off test result for PBX loaded into the Heavy Wall Penetrator (HWP) generic test unit is shown on Figure 6. Pressure from the burning explosive caused a loading port rupture. The explosive proceeded to burn mildly until it was all consumed. Composition B detonated under the same test conditions.

Figure 7 shows a Naturally Fragmenting (NF) generic test unit with added end confinement that was loaded with a PBX, after a multiple bullet impact test (five 20-mm rounds at 1120 m/sec and 50 msec intervals). The case split open in the back, but the explosive only burned. The Composition B reaction was just a little more violent under the same conditions, producing a deflagration. Under the heavier confinement of a 127-mm projectile, Composition B detonated while the PBX still produced only a burning reaction. The same test conducted on the PBX in a generic bomb case caused mild explosive burning, as shown in Figure 8 (bullet exit side). H-6 produced an explosion reaction in this configuration, Figure 9.

Some of the tests discussed above are new, so there is not much of a data base on results for a variety of explosives. However, the test results so far indicate that in some situations it takes more input energy to cause an explosive reaction for insensitive PBX's, compared to conventional TNT-based or pressed explosives. The PBX's also often appear to react less violently when explosive reactions are started under test hardware confinement.

CONCLUSIONS

Two new families of rubbery PBX's developed by the U.S. Navy are high-performance explosives with good vulnerability characteristics. Work is being done to define better methods for predicting ordnance performance and vulnerability, but this still cannot be done for many conditions. It is necessary to do large-scale hardware tests to obtain data and to demonstrate that predictions are valid.

The long time and high costs associated with large-scale testing has caused the Navy to undertake a new Explosives Advanced Development Program. Work is being done under this program on pilot plant scale-up and large-scale vulnerability and performance testing of new explosives.

Recent large-scale testing of several new rubbery PBX's show that they have better vulnerability behavior than counterpart, conventional TNT-based or pressed explosives. The improved vulnerability behavior of these new PBX's is thought to be due primarily to their rubbery physical properties.

TABLE 1. COMPOSITIONS OF UNDERWATER PBX'S

INGREDIENTS	WEIGHT PERCENT	
	PBXN-103	PBXN-105
AMMONIUM PERCHLORATE	40.0	49.80
ALUMINUM POWDER	27.0	25.80
TRIMETHYLOLETHANE TRINITRATE	23.0	
TRIETHYLENEGLYCOL DINITRATE	2.5	
PELLETIZED NITROCELLULOSE	6.0	
ETHYL CENTRALITE	1.3	
RESORCINOL	0.2	
RDX		7.00
BIS DINITROPROPYL ACETAL/FORMAL		12.92
POLYOXYETHYLENE GLYCOL		3.13
TRIMETHYLOLPROPANE		0.34
TOLUENE DIISOCYANATE		0.83
PHENYL BETA NAPHTHYLAMINE		0.17
DIBUTYLTIN DILAURATE		0.01

TABLE 2. PROPERTIES OF UNDERWATER PBX'S

PROPERTY	EXPLOSIVE H-6**	PBXN-103	PBXN-105
THEORETICAL MAXIMUM DENSITY (TMD, G/CM^3)	1.79	1.89	1.90
DROP-WEIGHT IMPACT SENSITIVENESS (50% POINT, MM)	1100	100-200	180-200
NOL LSGT (50% POINT, GAP, MM) (DENSITY)	42 (1.75)	23 (1.89)	30 (1.90)
CRITICAL DIAMETER (MM) (DENSITY)	5.1 $<$7.6 (1.72)	27-29 (1.89)	60-90 (1.90)
DETONATION VELOCITY (MM/μSEC) (DENSITY)	7.5 (1.75)	6.2 (1.89)	5.9 (1.90)
MECHANICAL PROPERTIES (TENSILE, 1.0 MPA = 145 PSI)			
MAXIMUM STRESS (MPA)	2.63	0.45	1.23
STRAIN AT MAX. STRESS (%)	0.02	12	13
TANGENT MODULUS (MPA)	12,310	5	11
THERMAL STABILITY (^{o}C)*	79	170	200
SUSAN TEST (VIOLENT REACTION VEL., 28 KPA AT 3M, M/SEC)	262	~90	~110

*DTA ONSET OF FIRST "LARGE" EXOTHERM OR ENDOTHERM (10^{o}C/MIN., 20 MG SAMPLE).

**45RDX/30TNT/20AL/5WAX

TABLE 3. COMPOSITION OF A RUBBERY-NITRAMINE PBX

INGREDIENTS	WEIGHT PERCENT
RDX	75.00
BIS DINITROPROPYL ACETAL/FORMAL	18.55
POLYOXYETHYLENE GLYCOL	4.50
TRIMETHYLOLPROPANE	0.49
TOLUENE DIISOCYANATE	1.19
PHENYL BETA NAPHTHYLAMINE	0.25
FERRIC ACETYLACETONATE	0.02

TABLE 4. PROPERTIES OF A RUBBERY-NITRAMINE PBX

PROPERTY	COMP A-3**	EXPLOSIVE COMP-B***	PBX
THEORETICAL MAXIMUM DENSITY (TMD, G/CM^3)	1.67	1.73	1.65
DROP-WEIGHT IMPACT SENSITIVENESS (50% POINT, MM)	800-900	600	430
NOL LSGT (50% POINT, GAP, MM) (DENSITY)	58 (1.65)	51 (1.70)	49 (1.64)
CRITICAL DIAMETER (MM) (DENSITY)	–	2.4 (1.71)	< 3 (1.64)
DETONATION VELOCITY (MM/μSEC) (DENSITY)	8.52 (1.67)	7.86 (1.67)	7.90 (1.65)
MECHANICAL PROPERTIES (TENSILE, 1.0 MPA = 145 PSI)			
MAXIMUM STRESS (MPA)	1.13	1.43	0.32
STRAIN AT MAX. STRESS (%)	0.04	0.02	10
TANGENT MODULUS (MPA)	5040	11,700	6
THERMAL STABILITY (°C)*	190	80	~200
SUSAN TEST (VIOLENT REACTION VEL., 28 KPA AT 3M, M/SEC)	270	210-240	415

*DTA ONSET OF FIRST "LARGE" EXOTHERM OR ENDOTHERM (10°C/MIN., 20 MG SAMPLE).

**91 RDX/9WAX

***59.4 RDX/39.6TNT/1.0WAX

TABLE 5. EAD PROGRAM WORK EFFORTS

- IMPROVE EXPLOSIVES PRODUCIBILITY AND CONDUCT PILOT PLANT SCALE-UP.
- BETTER CHARACTERIZE EXPLOSIVES AND CONDUCT LARGE-SCALE TESTS.
- DEVELOP PREDICTIVE METHODS TO IMPROVE WARHEAD DESIGN AND USE.
- PROVIDE A PRINTED DOCUMENT AND A COMPUTERIZED STORAGE-RETRIEVAL DATA BASE ON EXPLOSIVES PROPERTIES.
- COORDINATE EXPLOSIVES DEVELOPMENT WITH WEAPON DEVELOPERS, SPONSORS, PRODUCTION GROUPS, AND OTHERS DOING EXPLOSIVES DEVELOPMENT.

TABLE 6. EXPLOSIVES ADVANCED DEVELOPMENT PHASES

- PHASE I PRODUCIBILITY ASSESSMENT

  A SMALL-SCALE LABORATORY STUDY TO IMPROVE PRODUCIBILITY AND TO OBTAIN PROPERTIES DATA.

- PHASE II PILOT PLANT SCALE-UP

  SCALE-UP OF LABORATORY COMPOSITIONS TO EVALUATE PROCESSING VARIABLES, AND TO DETERMINE THE BEST EQUIPMENT AND PROCEDURES FOR PROCESSING EXPLOSIVES.

- PHASE III LARGE-SCALE SAFETY TESTS

  EXPLOSIVES ARE LOADED INTO A VARIETY OF TEST HARDWARE AND SUBJECTED TO HAZARDS AND VULNERABILITY TESTS (FUEL FIRE, FRAGMENT IMPACT, SYMPATHETIC DETONATION, ETC.).

- PHASE IV LARGE-SCALE PERFORMANCE TESTS

  EXPLOSIVES ARE LOADED INTO TEST HARDWARE AND SUBJECTED TO PERFORMANCE TESTS (AIR BLAST, FRAGMENTATION, UNDERWATER OUTPUT, ETC.)

- PHASE V DOCUMENTATION

  FINALIZATION OF SPECIFICATIONS AND INCORPORATION OF EXPLOSIVES' DATA INTO AN EXPLOSIVES PROPERTIES DOCUMENT.

TABLE 7. SAFETY RANKING SCHEME

ATTRIBUTES	WEIGHTING FACTOR *	PBX EXAMPLE RATING **	PBX EXAMPLE SCORE
COOK-OFF			
FAST COOK-OFF	20	10	200
SLOW COOK-OFF	15	4	60
SUBTOTAL	35		260
VULNERABILITY			
SYMPATHETIC DETONATION	8	10	80
MULTIPLE BULLET	8	3	24
SINGLE FRAGMENT	5	3	15
MULTIPLE FRAGMENT	8	7	56
SHAPED CHARGE	5	1	5
SUBTOTAL	34		180
SENSITIVITY			
LARGE-SCALE GAP	3	2	6
SUSAN	8	10	80
WEDGE	2	5	10
CRITICAL DIAMETER	2	7	14
AQUARIUM	3	8	24
FRICTION	1	10	10
DROP-WEIGHT	1	5	5
SUBTOTAL	20		149
PROPERTIES			
ISOTHERMAL COOK-OFF	5	2	10
GROWTH & EXUDATION	3	9	27
GLASS TRANSITION	2	10	20
DENSITY VARIATION	1	10	10
SUBTOATL	11		67
TOTAL	100		656

* TOTAL OF 100 POINTS

** RANGE FROM 0 TO 10. VALUE IS OBTAINED FROM EQUATIONS THAT EVALUATE VIOLENCE OF REACTION FOR COOK-OFF AND VULNERABILITY (EXCEPT SYMPATHETIC DETONATION) AND RELATIVE PERFORMANCE COMPARED TO OTHER STANDARD EXPLOSIVES FOR SYMPATHETIC DETONATION, SENSITIVITY AND PROPERTIES.

TABLE 8. PRE-1970 WR-50 TEST RESULTS

TYPE REACTION	SLOW COOK-OFF	FAST COOK-OFF	BULLET IMPACT	12-METER DROP
NO ACTION	0	0	90	229
BURNING	9	48	79	4
VIOLENT BURNING	2	7	15	0
EXPLOSION	4	3	3	2
L.O. DETONATION	2	7	35	0
H.O. DETONATION	8	5	3	0
TOTAL	25	70	225	235
% VIOLENT REACTION	64	31	25	1

TABLE 9. SUMMARY OF PBXN-103 WR-50 TEST RESULTS*

TYPE REACTION	SLOW COOK-OFF	FAST COOK-OFF	BULLET IMPACT	12-METER DROP**
NO ACTION	0	0	1	32
BURNING	5	15	8	0
DEFLAGRATION	3	6	4	0
EXPLOSION	3	10	7	0
DETONATION	6	0	0	0
TOTAL	17	31	20	32
% VIOLENT REACTION	53	32	35	0

* 45 KG to 550 KG EXPLOSIVE CHARGES IN ALUMINUM AND STEEL CASES.

** INCLUDES DROPS ONTO STUDS, AND MULTIPLE DROPS ONTO STUDS.

TABLE 10. RESULTS OF NON–ALUMINIZED PBX SAFETY AND VULNERABILITY TESTS

TEST ITEM (GENERIC PROJECTILES)	TEST	EXPLOSIVE: PBX	EXPLOSIVE: COMP A3
127-MM	FAST COOK-OFF	BURN	PARTIAL DETONATION
76-MM	FAST COOK-OFF	BURN	PARTIAL DETONATION
127-MM	SLOW COOK-OFF	BURN OR EXPLO.	DETONATION
76-MM	SLOW COOK-OFF	BURN	PARTIAL DETO./DETO.
127-MM	SYMPATHETIC DETO.	NO SYMP. DETO.	50% PT. = 180-250 MM
76-MM	SYMPATHETIC DETO.	NO SYMP. DETO.	50% PT. = 30 MM
76-MM MOD*	SUSAN IMPACT	V_c = 417 M/SEC	V_c = 364 M/SEC
3/5-127-MM **	SETBACK-SHOCK	BURNS	EXPLOSION

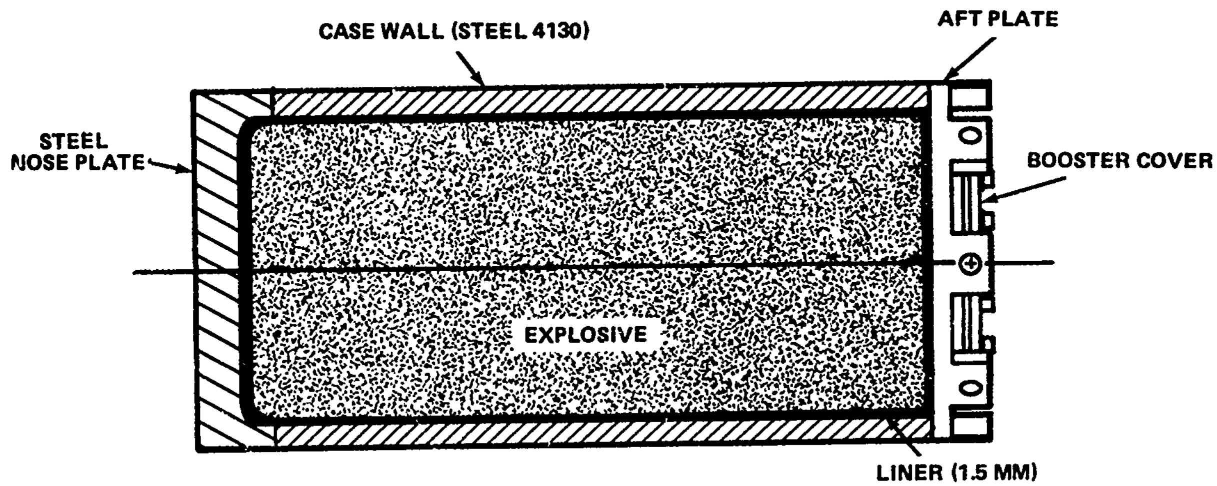
* MODIFIED 76-MM PROJECTILE, V_c = VELOCITY TO GIVE 28 KPA (4 PSI) OVERPRESSURE AT 3 METERS.

** THREE-FIFTHS SCALE, 127-MM PROJECTILE.

TABLE 11. RESULTS OF AN ALUMINIZED PBX VULNERABILITY TESTS

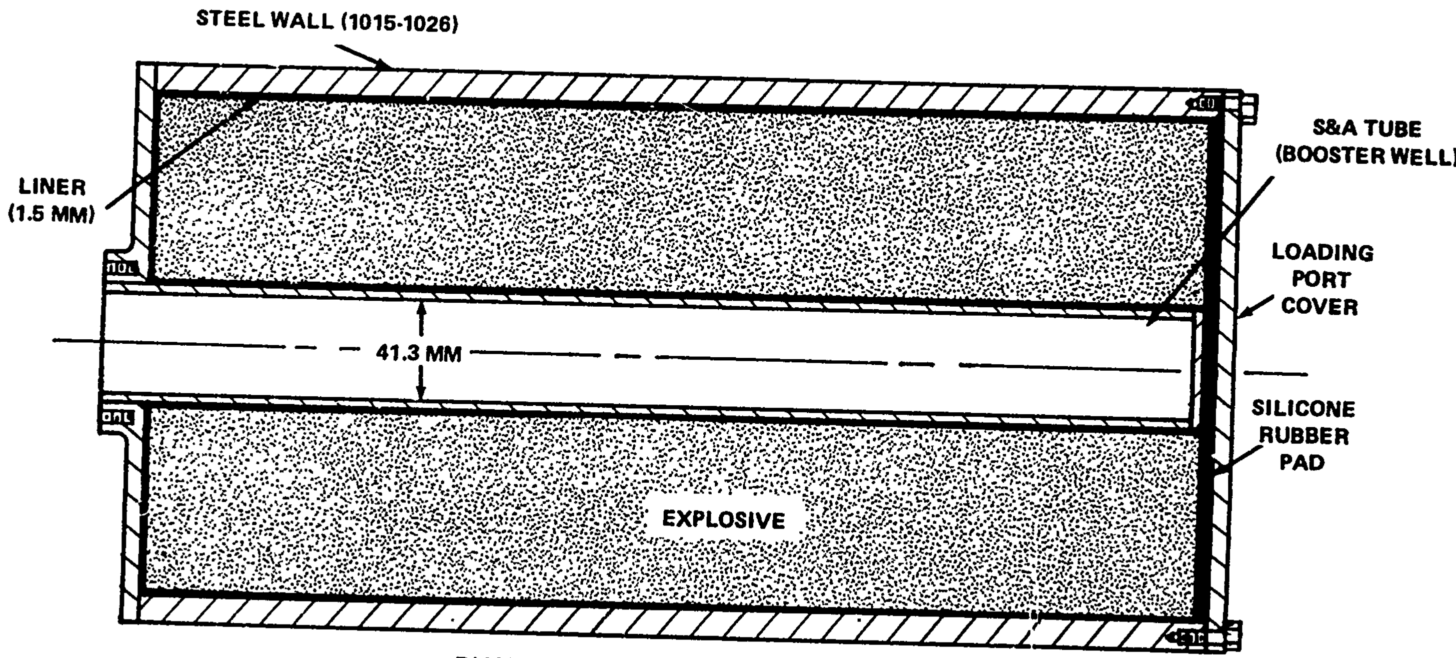
TEST ITEM *	TEST	EXPLOSIVE	
		COMP B	AL PBX
NF	TEMP. CYCLE	CRACKS & VOIDS	NO CHANGE
NF	VIBRATION	NO EFFECT	+11°C
HWP/PF/127-MM	FAST COOK-OFF	DETO	BURNING
HWP/PF	SLOW COOK-OFF	DETO/BURN	EXPLO/BURN
127-MM	SYMPATHETIC DETO	50% PT ~90 MM	NO DETO
NF	SHAPE CHG (M46)	DETO	DETO
NF/PF	MULTIPLE BULLET	DEFL	BURN
GENERIC BOMB	MULTIPLE BULLET	(H-6, EXPLO)	BURN
127-MM	MULTIPLE BULLET	DETO	BURN
NF	MULTIPLE FRAG	DETO (1910-2200 M/SEC)	EXPLO/BURN (2000-2180 M/SEC)
76-MM MOD	SUSAN	230 M/SEC	540 M/SEC

* NF = NATURALLY FRAGMENTING UNIT, HWP = HEAVY WALL PENETRATOR, PF = PREFORMED FRAGMENTS UNIT, 76-MM MOD = MODIFIED 76 MM PROJECTILE, AND 127-MM = 127-MM PROJECTILE



DESIGN PARAMETERS	
DIAMETER (MM)	203
LENGTH (MM)	406
MATERIAL THICKNESS (MM)	
WALL	12.7
CASE, AFT PLATE	12.7
NOSE PLATE	25.4
TOTAL WEIGHT (KG)	48.6
METAL PARTS (KG)	32.7
EXPLOSIVE WT. (KG)	16.0
CHARGE TO METAL RATIO (C/M)	
C/M EFFECTIVE	0.72

FIGURE 1. GENERIC HEAVYWALL PENETRATOR (HWP)



DIAMETER (MM)	203
LENGTH (MM)	380
WALL THICKNESS (MM)	9.5
EXPLOSIVE WEIGHT (KG)	16.4
CASE WEIGHT (KG)	17.3
TOTAL WEIGHT (KG)	37.7
CHARGE TO METAL RATIO (C/M)	
C/M EFFECTIVE	0.95

FIGURE 2. GENERIC NATURALLY FRAGMENTING (NF) UNIT

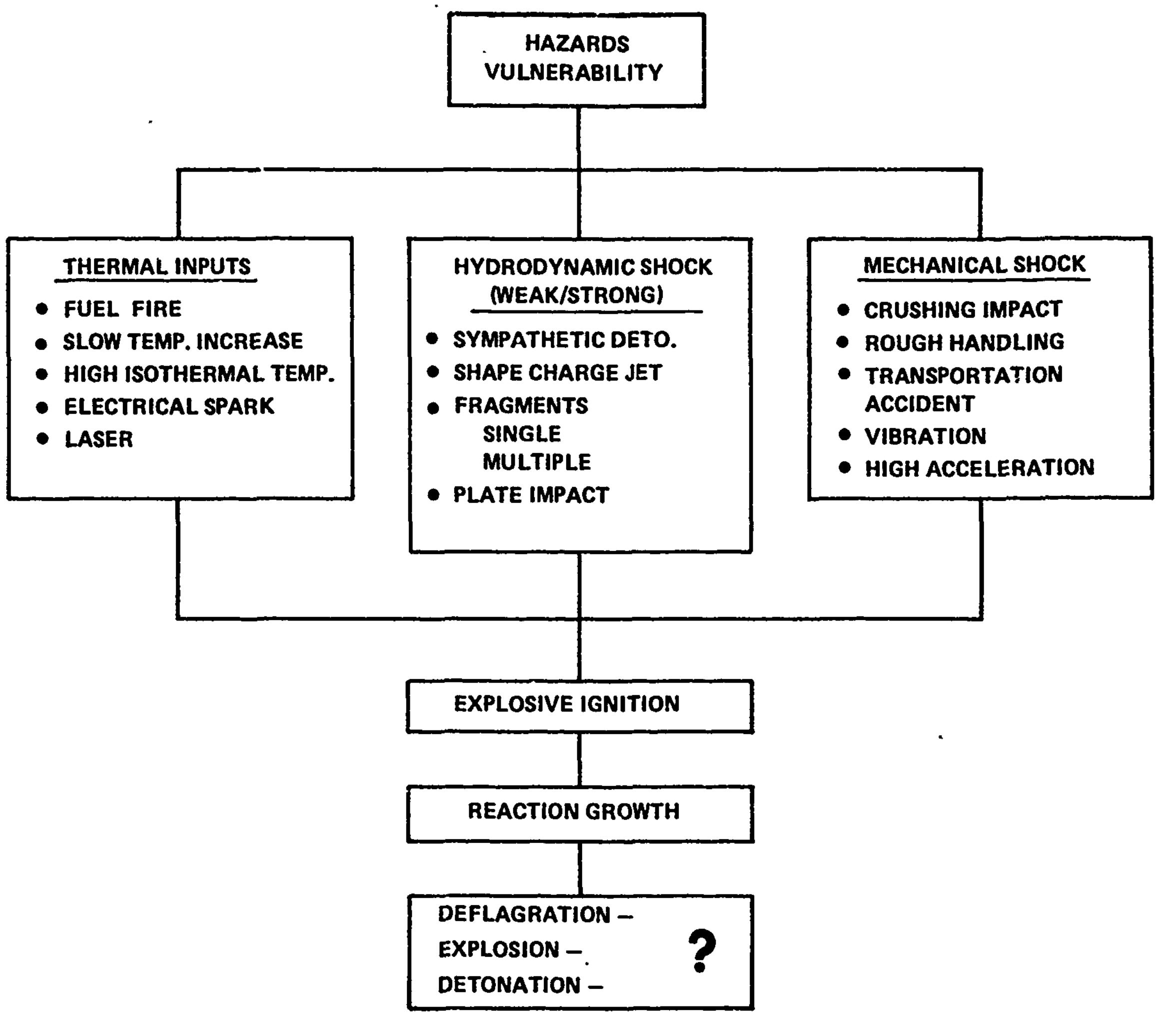


FIGURE 3. HAZARDS-VULNERABILITY BEHAVIOR

FIGURE 4. SYMPATHETIC DETONATION TEST SET-UP

FIGURE 5. SYMPATHETIC DETONATION PBX RESULTS (NO SEPARATION FROM DONOR)

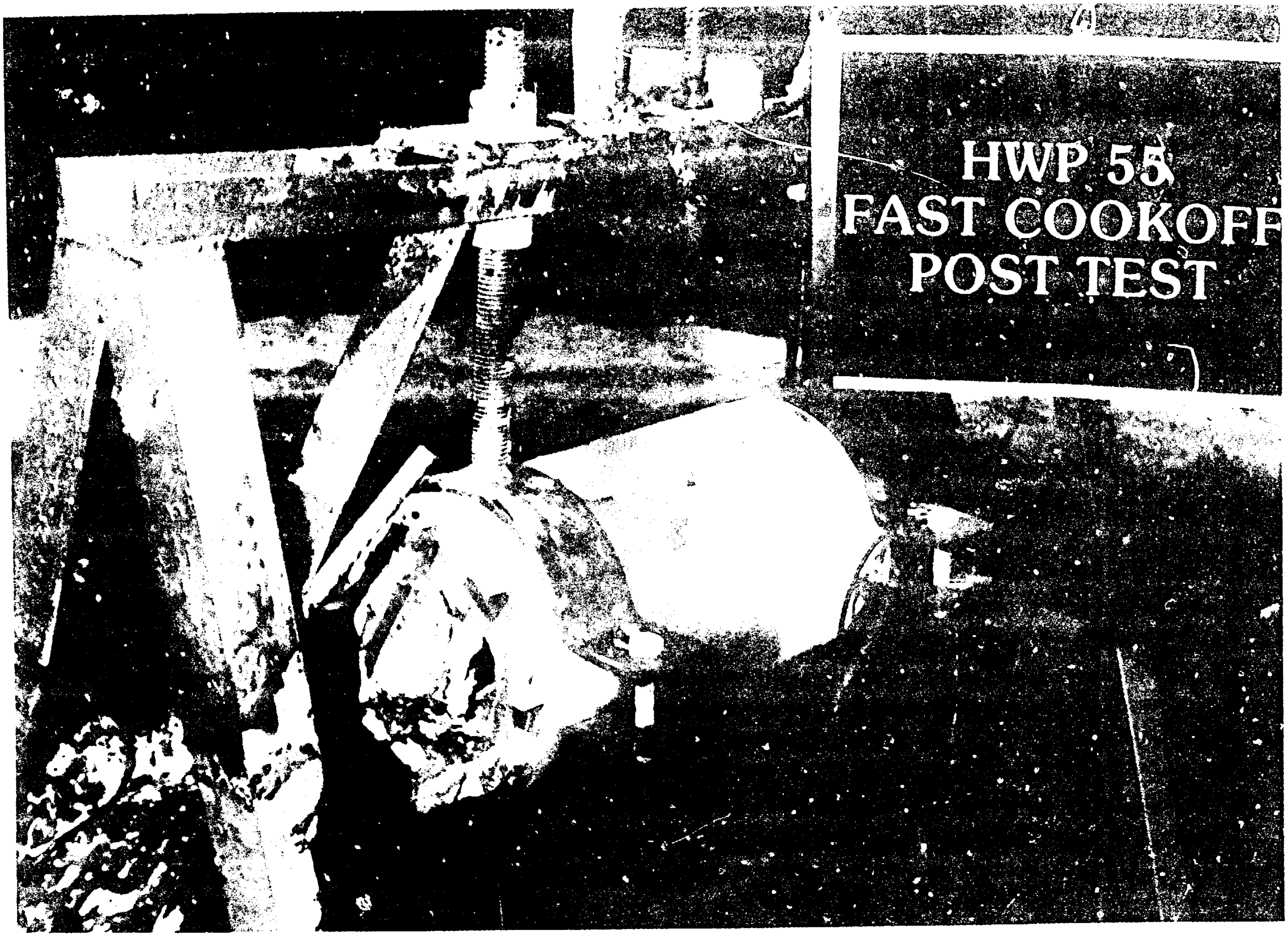


FIGURE 6. PBX FAST COOK-OFF (POST-TEST)

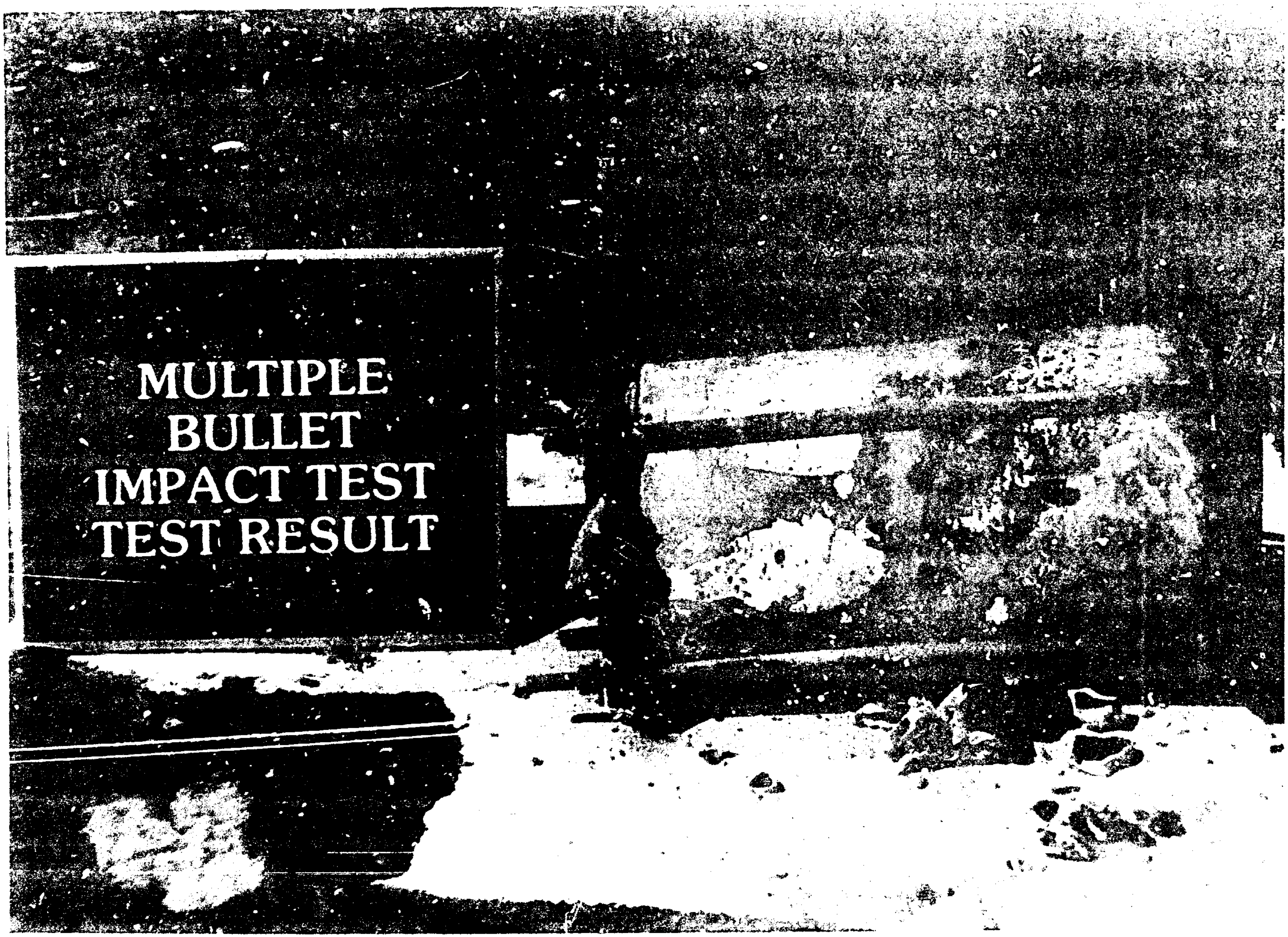


FIGURE 7. MULTIPLE BULLET IMPACT TEST RESULT FOR INSENSITIVE PBX (NF UNIT)

FIGURE 8. MULTIPLE BULLET IMPACT TEST RESULT FOR INSENSITIVE PBX

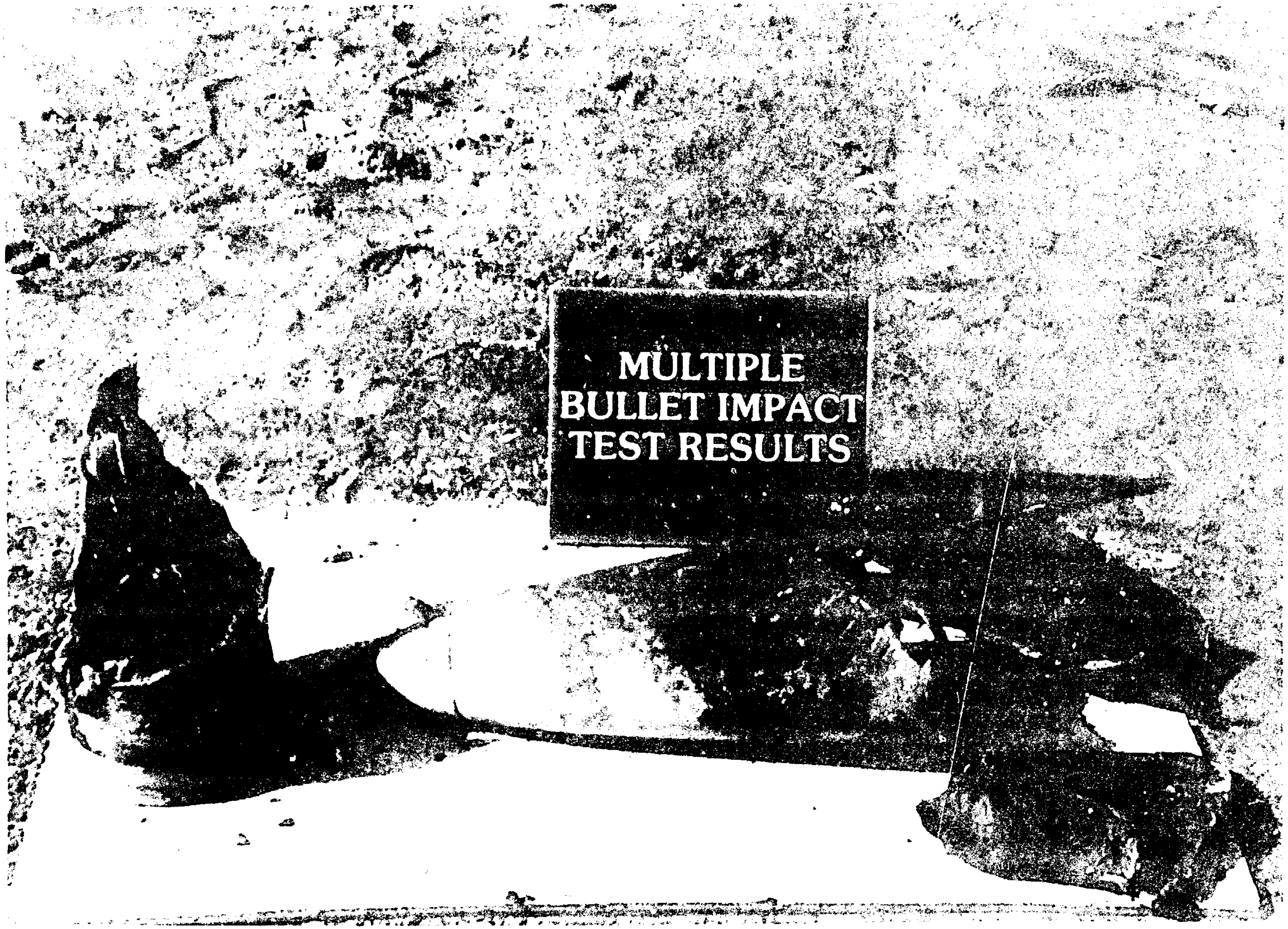


FIGURE 9. MULTIPLE BULLET IMPACT TEST RESULT FOR TNT BASED EXPLOSIVE